N64 14285
code-1
CR-55309

First Semiannual Report
NASA Contract NsG-458
June 1, 1963 - January 1, 1964

DETECTION TECHNIQUES FOR TENUOUS PLANETARY ATMOSPHERES

By

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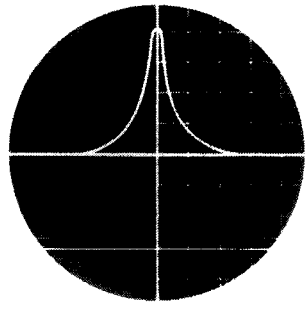

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June 1, 1963 - January 1, 1964

TO

Dr. T. L. K. Smull
Grants and Research Contracts Office Code SC
National Aeronautics and Space Administration
Washington, D. C. 20546

(X) OTS
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DETECTION TECHNIQUES FOR TENUOUS PLANETARY ATMOSPHERES

NsG-458

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[1964] 138 refs

(NASA Grant NsG-458)
(NASA CR-55379) OTS: $1.60 ph, $0.80 mf

I. INTRODUCTION

This program was set up to investigate chemisorption phenomena with the ultimate aim of developing devices for the investigation of tenuous planetary atmospheres. Since the program, as originally proposed, involved several semi-independent studies, this report will be divided into several parts in order to discuss the work done in each of these areas.

II. THE CHEMISORPTION DETECTOR FOR OXYGEN

This device was first suggested about three years ago when Langmuir's work, on the effect of oxygen on tungsten, came to the author's attention. Langmuir showed that chemisorption of oxygen raised the work function of tungsten and that this effect was highly specific for the gas and solid involved. This effect had been used for leak detection by Langmuir and others[1,2] but no attempt was made to develop the device as a quantitative detector.

With the kind assistance of Dr. G. P. Kuiper of the Lunar and Planetary Laboratory, a program was started to develop such a detector and investigate its behavior with mixtures of gases. The system finally settled upon was a tungsten filament cathode and a nickel anode, a drawing of the detector and a circuit schematic are shown in Fig. 1. For operation the filament is flashed to 2300°K to remove adsorbed gases and then allowed to cool to 1500°K. The fall-off of the electron emission current is then a sensitive function of the ambient oxygen pressure since at 1500°K the oxygen can be chemisorbed by the tungsten and thereby raise the filament work function. Typical curves for a series of oxygen pressures are shown

in Fig. 2. Each curve is the mean of five runs and the spread in the data is shown by the horizontal bars. The ultimate pressure of operation is set by the time available for the experiment, but is expected in general, to be about 10^{-11} - 10^{-12} torr. The device has proved to be quite reproducible and stable over long periods of time.

Originally some question was raised about the behavior of the system in mixtures of gases. From the known data of chemisorption it was expected that the effects of other gases would be small, but as a check, experiments were run in oxygen/nitrogen and oxygen/carbon dioxide ambients. In each case the effects were as expected; the system was quite insensitive to nitrogen at nitrogen oxygen ratios as high as ten to one. This work was used for a M.S. thesis in Aerospace Engineering by Mr. Donald Collins and a paper discussing the work will be published in the Review of Scientific Instruments for January 1964.

The work on CO_2 is continuing but our first results indicate that there is no significant effect of CO_2 at CO_2/O_2 ratios as high as ten to one.

Normally hot filament systems are monitored by a radiation pyrometer which requires careful adjustment and an optical window in the vacuum system. By installation of a platinum-platinum rhodium thermocouple near the hot filament we have been able to obtain a calibration curve for filament temperature vs. thermocouple output. Once this curve is available filament temperatures can be checked without using the optical pyrometer. This technique has proved to be quite sensitive and reproducible. The filament to thermocouple calibration curve can be obtained in a simple vacuum system without opening the U-H-V system more often than necessary. This method of filament control should be quite valuable for operation of the detector in a field experiment where it may be very inconvenient to use a

radiation pyrometer.

III. THE THORIATED TUNGSTEN FILAMENT FOR OXYGEN DETECTION

Langmuir's early work indicated that a small amount of thorium (1%) in tungsten substantially reduced the tungsten work function. He also noted that this thorium effect was easily destroyed by ambient oxygen. After discussions with Dr. Kuiper, we decided to investigate this effect for use as an ultra sensitive oxygen detector useful to pressures below 10^{-14} torr. The first series of experiments have been quite favorable and indicate at least a three-order of magnitude gain in sensitivity over the bare tungsten detector. This sensitivity is gained at the expense of an increase in operational complexity. For each run the thorium must be brought to the surface of the filament by careful heating. The filament is then flashed and allowed to cool to $1500^{\circ}K$, then the oxygen is admitted. The oxygen first combines with the thorium and thorium oxide is desorbed from the filament. The oxygen is then chemisorbed on the bare tungsten and the filament behaves as a standard chemisorption detector. The total change in emission current from thoriated tungsten to tungsten with chemisorbed oxygen is about 10^3 times that for tungsten-oxygen alone. This leads to the increased sensitivity mentioned earlier. It must be emphasized that this type of device is a "one shot" affair. After a single high sensitivity exposure, the detector must be reactivated to bring new thorium to the surface. Further work is being done to determine the best operating conditions. The ultimate sensitivity should be well in the 10^{-14} - 10^{-16} torr region.

IV. CHEMISORPTION DETECTOR FOR HYDROGEN

The possibility exists of using a chemisorption type of detector for hydrogen. This would mean developing a new filament, probably palladium.

This work is just getting under way now because of the need for developing safety precautions when using hydrogen. It seems that palladium will work satisfactorily but its sensitivity to oxygen must be explored. Ultimately it might be possible to have a single anode with two filaments, one for O_2 and the other for H_2; this would permit the experimenter to measure two of the most important components of a planetary atmosphere.

V. THE MOLECULAR BEAM SYSTEM

One of the most important ultimate uses of chemisorption detectors would be for measurement of slow protons and the neutral H_2/H ratio in space. This seems possible because of the expected difference in chemisorption between H_2 and H. Measurement of the H_2/H ratio with mass-spectrometers is difficult because of the dissociation and excited states produced by the ionizing electron beam. The chemisorption detector would have the advantage of small size, simplicity and freedom from the disturbing effects of ionizing electron beams. For investigation of this problem it was proposed that an ultra-high-vacuum molecular beam system be constructed with a furnace for production of H atoms. This work is now well under way and about one-half of the components are on hand at the present time. The system will be all stainless stell with copper seals, as shown in Fig. 3. The ultimate operational pressure is expected to be below 10^{-9} torr.

To test some of the proposed U-H-V components and techniques a 1/4 scale system was built during the past six months. This system is pumped by an 8 l/sec VacIon pump and easily reaches the 10^{-9} torr range. This model system has proved quite valuable for component testing and for preliminary research programs.

The large U-H-V system will be assembled in a new laboratory space generated by a NSF Facilities Grant. This space will be ready by June 1 and

assembly will start at that time. Components will be leak checked and cleaned for assembly as they are finished.

VI. MOLECULAR BEAM DETECTORS

As a preparation for our work with H_2 and H molecular beams we have been considering certain problems in beam detection and analysis. For beams of neutral species like H_2 the only feasible detector at present is the system which first ionizes a small fraction of the beam by electron bombardment and then detects these ions by electrometer techniques. The problems of such systems are well-known and a review has been given recently by Ramsey[3].

We have designed a new type of detector which can in principal detect a beam of any species and is not limited to species of low ionization potential. The device uses the technique first suggested by Müller[4,5] for his field ion microscope. The system operates by means of a fine tungsten point or tip and an adjacent nickel ring. The point or tip is driven at about 25,000 volts DC positive with respect to the ring. Atoms or molecules passing near the tip have an induced dipole moment because of the strong field gradient, and are then drawn to the tip. At the tip the molecules yield an electron to the Fermi level of the tip and these positive ions are then drawn to the ring. The ion current is then detected via an electrometer system.

Full details of the system will be reported when experiments have been performed to establish the best configuration. The effective cross sectional area for detection of an argon beam (a typical case) would be about 10^{-4} cm^2. If the beam intensity is (5) 10" particles/cm^2 sec, which is a typical value for a molecular beam system, the detected current would be

about $(5)10^{-15}$ amps. This is well within the limits of conventional electronic techniques.

Experiments are being planned to determine the actual values of the signal to noise ratio in a typical system. The importance of this detector lies in the fact that it will detect gases such as argon, helium, and hydrogen which are beyond the range of conventional surface ionization detectors. It can also be used for beams of metals such as copper. Copper is seldom used for molecular beam work because it cannot be detected by a standard surface ionization detector and the deposited copper short-circuits mass spectrometers. The field ion detector avoids both these problems quite easily.

The parameters of the system are being discussed with the molecular beam research group in the Physics Department. A short note describing the device is being prepared for the Review of Scientific Instruments.

VII. FUTURE PLANS

In the preceding sections we have indicated the direction of work for the second half of the contract year. First we wish to finish the runs on the oxygen detector with CO_2/O_2 mixtures. The experimental procedure for testing the thoriated-tungsten oxygen detector is somewhat clumsy at present since the thorium must be "sweated" to the surface each time. It may actually be simpler to coat the thorium on the tungsten from an external source, but this will require further investigation which will start when the O_2/CO_2 work is done.

The palladium detector for hydrogen will go into the vacuum system sometime in January and if the results are favorable the design for the atomic hydrogen oven will be put in the shop.

The large U-H-V system is in the fabrication stage and assembly will not begin until after June 1964 when space is available. Discussions have been held with other on-campus groups regarding studies in the large U-H-V system. A study of simulated lunar soils will probably be done in cooperation with the Lunar and Planetary Laboratory but this will not be allowed to interfere with the hydrogen detector program. The development work on the molecular beam detector is just beginning and we are still in the process of refining the analysis. It does appear that the system will work as planned but more study will be needed to obtain the most efficient geometry. Experimental work will be done later in 1964 when a microammeter is available.

It is expected that all the objectives of the program will be met within the available time and funds except for the assembly of the large U-H-V system. This U-H-V system will be delayed until the new laboratory space is available.

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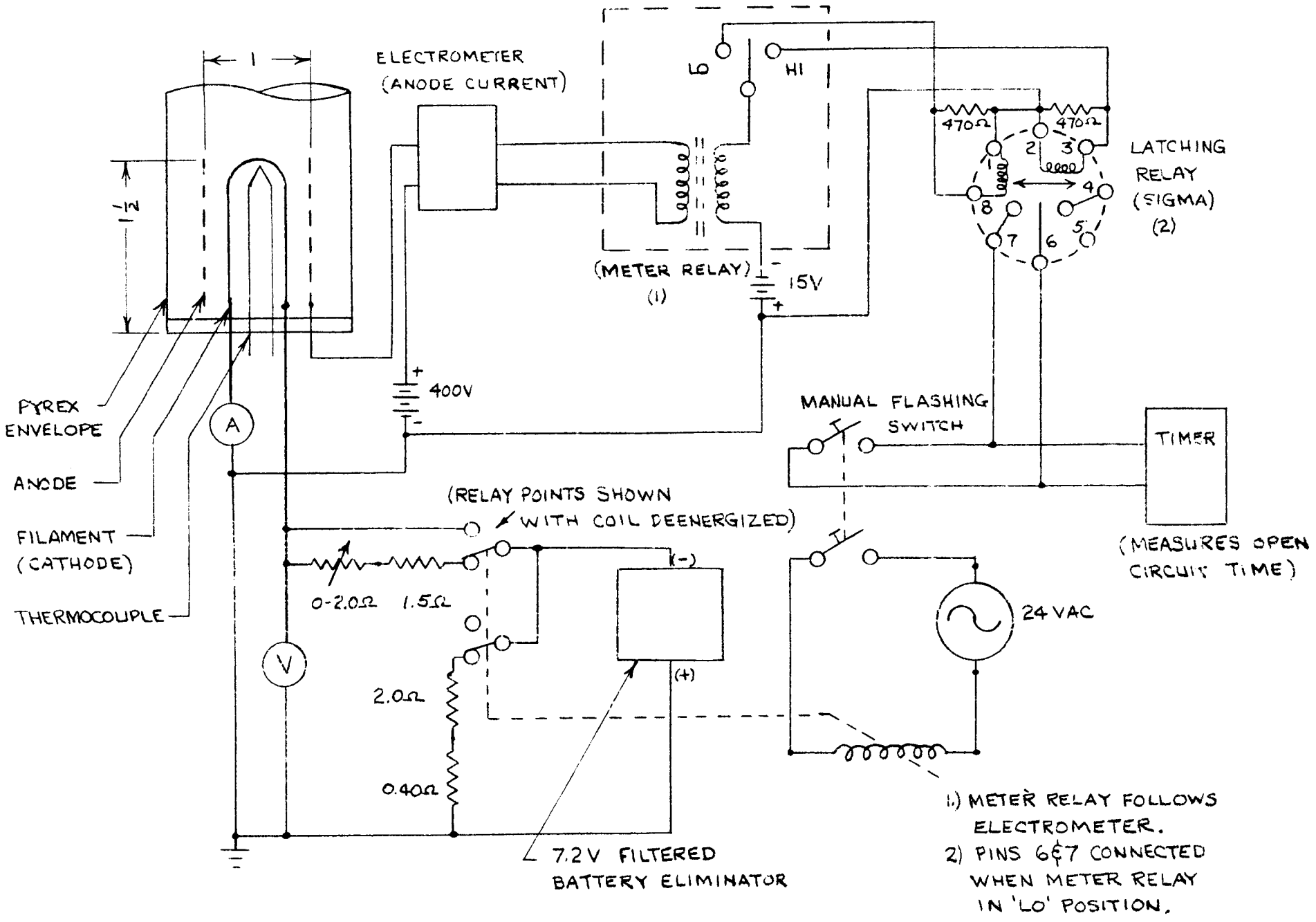
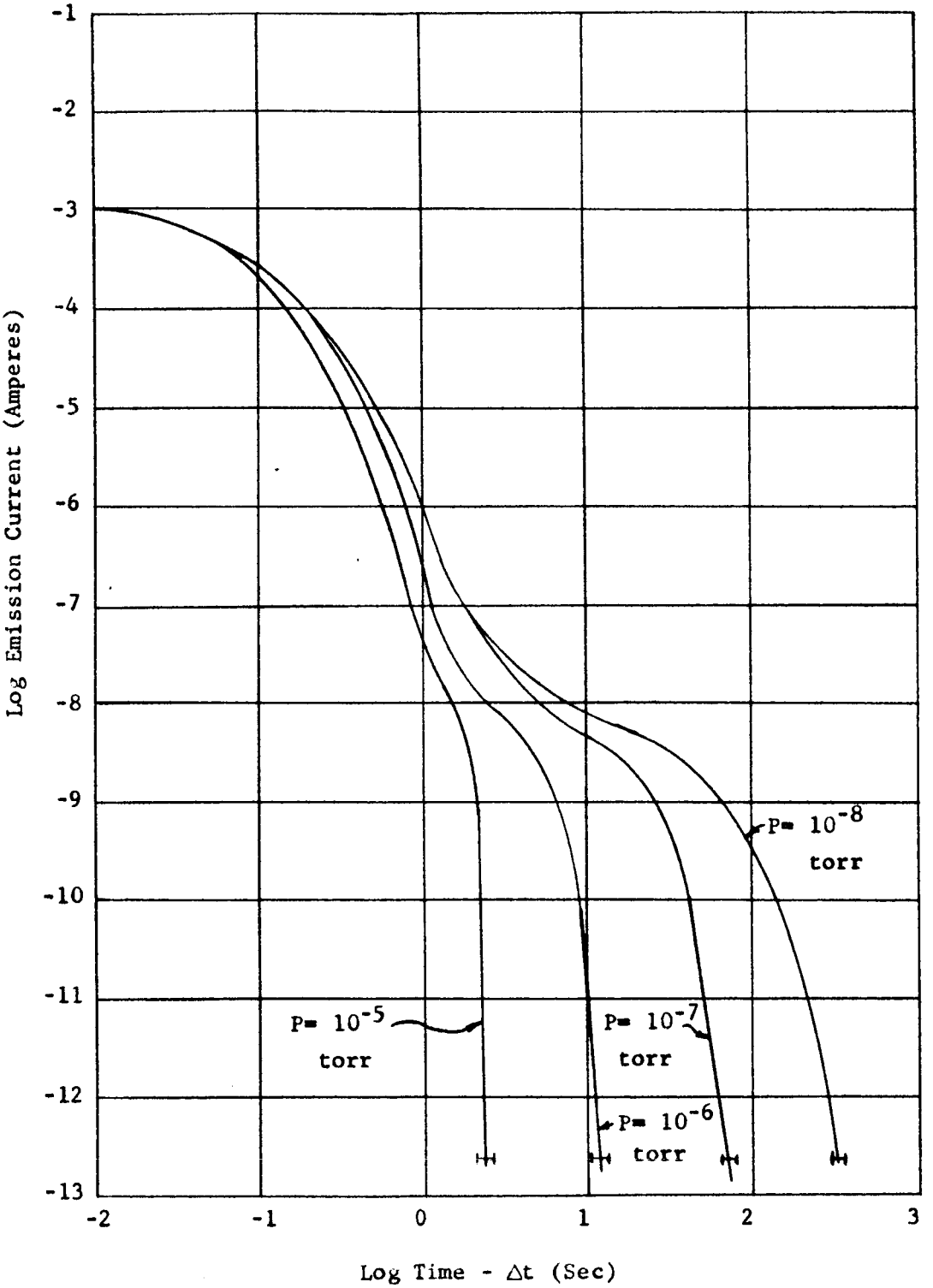


MEASUREMENT AND CONTROL CIRCUIT

FIGURE 1.



Experimental Performance Curves for the Chemisorption of Oxygen on Tungsten.

FIGURE 2.

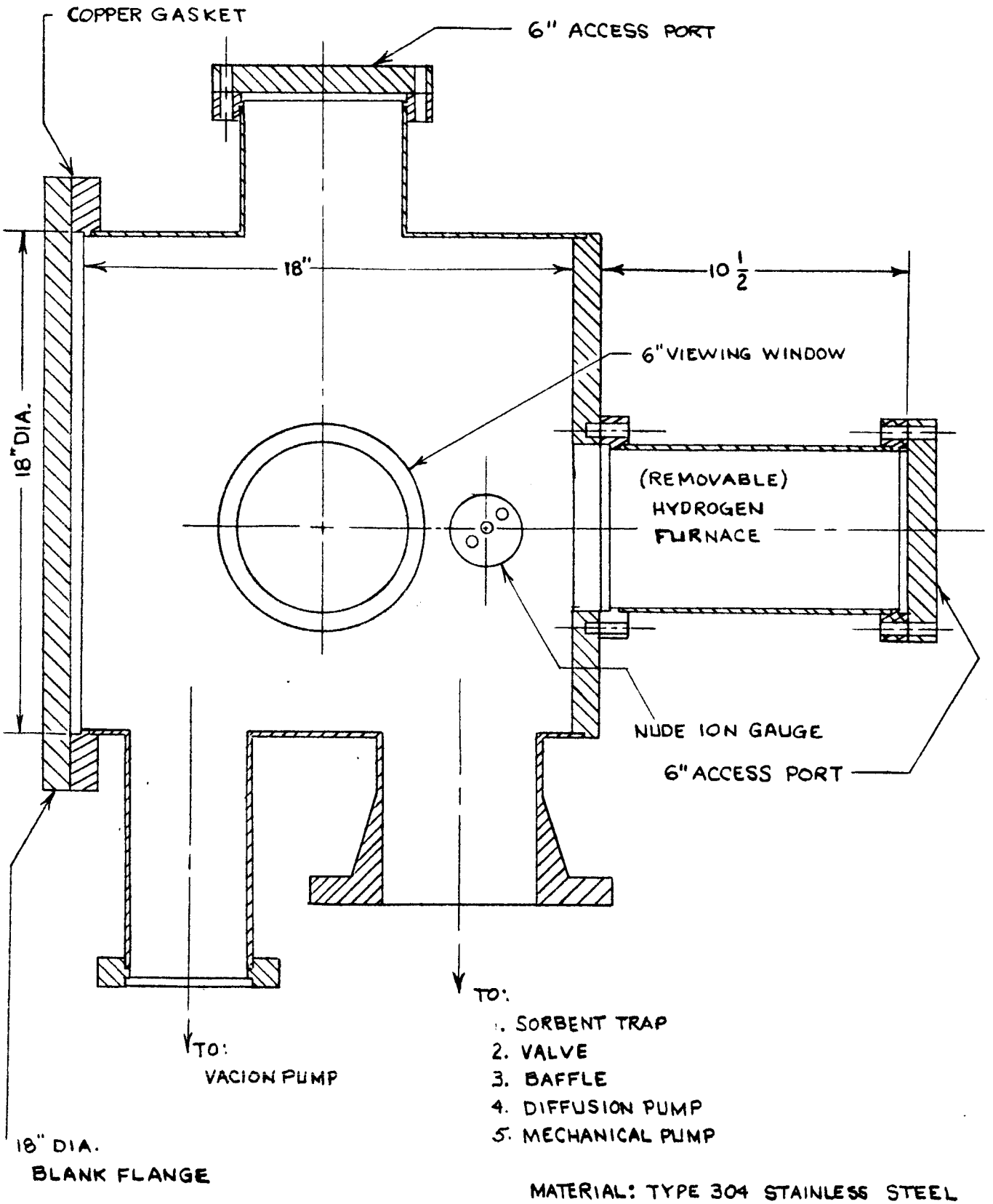


FIGURE 3.

MOLECULAR BEAM SYSTEM